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Fuel Cells for Military Applications

Preliminary Findings

by
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SERDP
Strategic Environmental Research and Development Program
Improving Mission Readiness through Environmental Research

In fiscal years 1993 and 1994 (FY93 and FY94), the U.S. Congress appropriated funds to advance the use of phosphoric acid fuel cells (PAFC) at Department of Defense (DoD) Installations. The U.S. Army Construction Engineering Research Laboratories (USACERL) was tasked with managing the Fuel Cell Demonstration Program, including developing turnkey PAFC packages, devising site selection criteria, screening DoD candidate installation sites against the site selection criteria to identify specific sites where the PAFCs were to be installed, and monitoring the installation process and subsequent system performance.

A total of 12, 200-kW PAFC power plants were purchased with the FY93 appropriations and 18 additional similar units were purchased with the FY94 appropriations; 11 fuel cells have been installed to date. Monitoring continues for electrical generation efficiency, degree of thermal utilization, air emission characteristics; and overall system reliability. As of 23 November 1996, the 11 fuel cells installed in the FY93 program have been operating for a combined total of over 83,425 hours, have generated over 14,607 MWh of electricity and over 23,255 MBtus of thermal energy, and have achieved an adjusted fleet availability of 88 percent. Updated information on the program can be found on the world-wide-web at www.dodfuelcell.com.

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In fiscal years 1993 and 1994 (FY93 and FY94), the U.S. Congress appropriated funds to advance the use of phosphoric acid fuel cells (PAFC) at Department of Defense (DoD) Installations. The U.S. Army Construction Engineering Research Laboratories (USACERL) was tasked with managing the Fuel Cell Demonstration Program, including developing turnkey PAFC packages, devising site selection criteria, screening DoD candidate installation sites against the site selection criteria to identify specific sites where the PAFCs were to be installed, and monitoring the installation process and subsequent system performance.

A total of 12, 200-kW PAFC power plants were purchased with the FY93 appropriations and 18 additional similar units were purchased with the FY94 appropriations; 11 fuel cells have been installed to date. Monitoring continues for electrical generation efficiency, degree of thermal utilization, air emission characteristics; and overall system reliability. As of 23 November 1996, the 11 fuel cells installed in the FY93 program have been operating for a combined total of over 83,425 hours, have generated over 14,607 MWh of electricity and over 23,255 MBtus of thermal energy, and have achieved an adjusted fleet availability of 88 percent. Updated information on the program can be found on the world-wide-web at www.dodfuelcell.com.

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Executive Summary

In fiscal year 1993 (FY93), the U.S. Congress appropriated $18,000,000 to advance the use of phosphoric acid fuel cells (PAFC) at Department of Defense (DoD) Installations. An additional $18,750,000 was appropriated for this same purpose in FY94. The U.S. Army Construction Engineering Research Laboratories (USACERL) was assigned the mission of managing the Fuel Cell Demonstration Program provided for by these appropriations. Specific tasks associated with USACERL's role in this program included developing turnkey PAFC packages, devising site selection criteria, screening DoD candidate installation sites against the site selection criteria to identify specific sites where the PAFCs were to be installed, and monitoring the installation process and subsequent system performance.

Under the FY93 program, a solicitation was prepared to purchase the developed turnkey PAFC Power Plant packages, which included purchase, site engineering, installation and startup, operation and maintenance training, and a 5-year warranty and maintenance and repair period. A total of 12, 200-kW PAFC power plants manufactured by ONSI Corporation, of South Windsor, CT, were purchased with the FY93 appropriations. As of July 1996, PAFC power plants have been installed and made operational at eleven sites. The remaining site (U.S. Naval Academy, MD) is currently under design. The 12 sites are:

1. Vandenberg Air Force Base (AFB), CA
2. Natick Soldier Systems Command, MA
3. Naval Education Training Center, Newport, RI
4. 934th Airlift Wing, MN
5. MCB Twenty Nine Palms, CA
6. Kirtland AFB, NM
7. Fort Eustis, VA
8. Nellis AFB, NV
9. Picatinny Arsenal, NJ
10. MCB Camp Pendleton, CA
11. Military Academy, West Point, NY
12. Naval Academy, MD.

Under the FY94 program, a total of 18 additional PAFC power plant packages similar to those purchased with the FY93 appropriation were purchased from the ONSI Corporation. Installation of these PAFCs is expected to be completed by the end of FY97. Sites selected to receive fuel cells under this program were:

1. 911th Airlift Wing, PA
2. Naval Air Station Jacksonville, FL
3. Naval Air Station Fallon, NV
4. Laughlin AFB, TX
5. Watervliet Arsenal, NY
6. Fort Huachuca, AZ
7. Fort Richardson, AK
8. Westover ARB, MA
9. Little Rock AFB, AR
10. Stennis Space Center, MS
11. Davis Monthan AFB, AZ
12. Edwards AFB, CA
13. Fort Bliss, TX
14. Pine Bluff Arsenal, AR
15. CBC, Port Hueneme, CA
16. Barksdale AFB, LA
17. National Defense Center for Environmental Excellence (NDCEE), PA
18. Navy Subase-Groton, CT.

All the fuel cells installed as a result of this program are being monitored for electrical generation efficiency, degree of thermal utilization, air emission characteristics, and overall system reliability. As of 23 November 1996, the fuel cells in the FY93 program have been operating for a combined total of over 83,425 hours, have generated over 14,607 MWh of electricity and over 23,255 MBtus of thermal energy, and have achieved an adjusted fleet availability of 88 percent.

Foreword

This study was conducted for the Strategic Environmental Research Development Program (SERDP), under SERDP Work Unit 641-96, "Fuel Cells for Military Applications." This work was funded by the following agencies to manage the DoD fuel cell demonstration program and to monitor the fuel cells' long-term performance at the DoD sites: (1) Strategic Environmental Research and Development Program (SERDP), (2) Office of the Assistant Secretary of Defense (OASD), (3) Air Force Civil Engineering Services Agency (AFCESA), (4) Naval Facilities Engineering Services Center (NFESC), (5) Assistant Chief of Staff for Installation Management (ACSIM). The technical monitor was Michael Hathaway, SERDP.

The work was performed by the Utilities Division (UL-U) of the Utilities and Industrial Operations Laboratory (UL), U.S. Army Construction Engineering Research Laboratories (USACERL). The USACERL principal investigator was Dr. Michael J. Binder. Martin J. Savoie is Chief, CECER-UL-U; John T. Bandy is Operations Chief, CECER-UL; and Gary W. Schanche is the associated Technical Director, CECER-UL. The USACERL technical editor was William J. Wolfe, Technical Resources.

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1 Introduction

Background

The supply of reliable, cost-effective electric power with minimal environmental impact is a constant concern of Department of Defense (DoD) installation energy personnel. Electricity purchased from the local utility is expensive since it represents only about 30 percent of the original energy input at the generating station due to generation and distribution inefficiencies. Because of air-conditioning and other large cyclic loads, the demand portion of an installation's electric bill can exceed 50 percent of the total bill.

While the electric utilities in the United States have a very good record of reliability, there is significant potential for improving the security of electrical power supplied by using on-site power generation. On-site, dispersed power generation can reduce power outages due to weather, terrorist activities, or lack of utility generating capacity. In addition, as increased emphasis is placed on global warming, acid rain, and air pollution in general, the development of clean, highly efficient power producing technologies is not only desirable, but mandatory. The fact that the majority of central heat plants on U.S. military installations are nearing the end of their useful lives has created an opportunity to replace outdated existing equipment with modern technologies.

The "fuel cell" is one such candidate technology. A fuel cell is an electrochemical device that converts fuel directly into electricity and heat. In a typical fuel cell, gaseous fuels are fed continually to the anode, and an oxidant (usually air) is fed continually to the cathode. The electrochemical reactions take place at the electrodes to produce electricity. While a fuel cell is similar to a battery, the maximum energy available in a battery is determined by the finite amount of stored reactant. Because a fuel cell is fed a continuous supply of fuel and oxidant, it can theoretically produce energy as long as these inputs are available.

In typical commercial or industrial facilities, steam or hot water is produced in a boiler and electricity is generally purchased from the local utility. Fuel cells are typically more efficient than conventional energy systems because both the electric

and thermal outputs can be used simultaneously. Additionally, fuel cells have very high electrical conversion efficiencies, typically between 40 and 65 percent—depending on the type of fuel used. The efficiency of a fuel cell power plant, with thermal energy recovery, can be over 80 percent, compared to efficiencies of 35 percent or less for a typical power generation plant. Reduced operating costs associated with high efficiencies can make fuel cell power plants economically attractive for DoD facilities where there is a simultaneous demand for thermal and electrical energy. Thermal energy demand can include a need for domestic hot water (DHW), process steam, heating, or cooling (via absorption chillers). In addition to the energy and cost savings, fuel cell power plants offer the advantages of a reliable source of electricity, reduced environmental impact, reduced utility vulnerability, and improved survivability.

In fiscal year 1993 (FY93), the U.S. Congress appropriated $18,000,000 to advance the utilization of phosphoric acid fuel cells (PAFC) at DoD Installations. In FY94, an additional $18,750,000 was appropriated for this same purpose. The U.S. Army Construction Engineering Research Laboratories (USACERL) was tasked with managing the Fuel Cell Demonstration Program provided for by these appropriations. Specific tasks associated with USACERL's management role in this program included developing turnkey PAFC packages, devising site selection criteria, screening DoD candidate installation sites against the site selection criteria to identify specific sites where the PAFCs were to be installed, and monitoring the installation process and subsequent system performance.

Objectives

The objectives of this study were to provide a field demonstration of PAFC applications at U.S. military installations, and to document lessons learned to be applied to the development of application guidelines for eventual implementation of fuel cell technologies within the DoD.

Approach

1. Site selection criteria were developed and DoD candidate installation sites against the site selection criteria to identify specific sites where the PAFCs were to be installed.
2. Turnkey PAFC packages were purchased and installed at the selected installations.
3. The installation process was monitored. (Subsequent system performance continues to be monitored.)

Mode of Technology Transfer

It is anticipated that the information derived from this study will be applied to the development of application guidelines for eventual implementation of fuel cell technologies within the DoD.

2 FY93 and FY94 DoD Fuel Cell Demonstration Program

The FY93 Defense Appropriations Act provided $6 million worth of equipment procurement funds per Service for the implementation of "non-developmental item natural gas fuel cells currently in production in the United States ... for power generation at military installations ..." with the recommendation that "... some of the cells be installed at locations in need of enhanced air quality ..." The purposes of this demonstration program are to stimulate growth in the fuel cell industry, which will lower costs through economies of scale and competition, and to determine the role fuel cells should play in DoD long-term energy supply strategy. The three Services, acting through the Defense Utilities Energy Coordinating Council (DUECC), requested that USACERL, a U.S. Army Corps of Engineers research laboratory affiliated with the University of Illinois at Urbana-Champaign, coordinate this fuel cell demonstration program for all three Services. Specific tasks associated with USACERL's coordination of this program included:

1. Developing turnkey Phosphoric Acid Fuel Cell Power Plant packages
2. Evaluating potential DoD site installation candidates to identify the specific sites where the PAFCs will be installed
3. Monitoring the electrical generation efficiency, degree of thermal utilization, air emission characteristics, and overall system reliability of the PAFCs to determine the economic and environmental benefits of owning and operating these systems
4. Developing of application guidelines based on the results of this program for the implementation of PAFC technology at DoD facilities
5. Documenting all aspects of the entire DoD Fuel Cell Demonstration Program.

A solicitation was prepared for the purchase of turnkey Phosphoric Acid Fuel Cell Power Plant packages, to include purchase, site engineering, installation and startup, operation and maintenance training, and a 5-year warranty, maintenance, and repair period. Following a negotiation period, ONSI Corporation was awarded a contract for the purchase of these turnkey PAFC systems. The terms of this contract involve cost-sharing on the part of ONSI Corporation, and calls for partnering with the local utility serving the selected posts. A total of 12, 200-kW PAFCs were purchased with the FY93 Appropriations and have been, or will be, installed at specific DoD installation sites having been identified through contract modifications.

Site Selection Criteria

Initial candidate sites were identified by Army, Air Force, and Navy/Marine Corps Headquarters by soliciting their respective Major Commands/Major Claimants. As awareness of the program grew, individual installations requested to become a part of this program. Initial screening of candidate sites was performed through an economic analysis based on total electricity and natural gas usage and average unit costs as provided by the Defense Energy Information System (DEIS). This economic analysis considered the electrical savings available through operation of a fuel cell power plant, the associated natural gas costs to operate the system, and the natural gas savings obtainable through recovery of the by-product thermal energy.

Installations that appeared to be good potential candidates as a result of this initial screening were then asked to submit copies of their actual past utility bills for a 12-month period so the economic analysis could be refined using actual monthly energy consumption and utility rate schedule data. In addition, each candidate installation was asked to provide information regarding the degree of air quality attainment for the region in which they were located, as well as a description of the intended application for the recovered by-product thermal energy and an estimate of the amount of this recovered thermal energy that they could use. At the same time, potential opportunities for financial leveraging through cost sharing and/or rebates by the local utilities providing service to these candidate sites were investigated.

Efforts were also made to ensure equal distribution of fuel cell installation sites among the three Services, and to provide as wide a geographical and climatic distribution as feasibility allows. Site visits were then made to those installations that still appeared to be good potential candidate sites at the end of the evaluation. These site visits allowed for refinement of the estimate of by-product thermal energy usage, an analysis of the logistical factors surrounding potential fuel cell installation (e.g., distance from gas line, lengths of pipe and wiring runs, availability of sufficient land space for siting, etc.), and the development of a conceptual design package. The successful candidate sites were identified to the ONSI Corporation to be selected installation sites through individual contract modifications. A kickoff meeting was held on site shortly after each contract modification to initiate the design and installation process.

Current Status

Eleven ONSI Model PC25B™ PAFCs and one Model PC25A™ have been installed and are operational at:

1. Vandenberg Air Force Base (AFB), CA (one PC25A™ was installed here)
2. Natick Soldier Systems Command, MA
3. Naval Education Training Center, Newport, RI
4. The 934th Airlift Wing, MN
5. MCB Twenty-Nine Palms, CA
6. Kirtland AFB, NM
7. Fort Eustis, VA
8. Nellis AFB, NV
9. Picatinny Arsenal, NJ
10. MCB Camp Pendleton, CA
11. Military Academy, West Point, NY.

A PAFC is also slated for installation at the Galley at the U.S. Naval Academy, MD during 1997 as part of an overall building renovation project. Chapter 3 of this report describes each of these sites (with the exception of Vandenberg AFB). The Air Force opted to provide part of the FY93 appropriation directly to Vandenberg AFB to allow the base to purchase an ONSI Model PC25A™ PAFC from the Southern California Gas Company as part of a Fuel Cell Evaluation Program that Vandenberg AFB had previously initiated. Since this site fell outside the scope of the USACERL coordination effort, the following discussion does not include Vandenberg AFB. Table 1 summarizes the sites, building applications, thermal applications, and estimated annual savings.

Operational Experience

Operational experience to date has demonstrated an unadjusted DoD fleet wide availability in excess of 71 percent. In January 1996, problems related to fuel cell makeup water chemistry at certain individual sites caused several of the fuel cells to be shut down for identification and correction of the problem. The history, nature, and correction of these problems is discussed in the following section. Table 2 summarizes the operational experience of the installed fuel cells, in terms of both the unadjusted and adjusted availability due to these water chemistry problems.

Table 1. FY93 DoD fuel cells application and estimated savings summary.

Site	Building Application	Thermal Application	Estimated Annual Savings
Vandenberg AFB, CA	Launch operations control center	Domestic hot water (DHW)	$32,000
U.S. Army Soldier Systems Command, MA	Central heating plant	Boiler makeup water & condensate return	$47,000
Naval Education Training Center, Newport, RI	Central heating plant	Boiler makeup water	$103,000
MCB Twenty-Nine Palms, CA	Hospital	DHW	$46,000
934th Airlift Wing, MN	Central heating plant	Boiler Condensate Return	$17,000
Kirtland AFB, NM	Central heating plant	Boiler makeup water	$58,000
Fort Eustis, VA	Recreation facility	DHW, swimming pool	$38,000
Nellis AFB, NV	Barracks complex	DHW, heat pump	$34,000
Picatinny Arsenal, NJ	Boiler plant	Boiler makeup water	$95,000
MCB Camp Pendleton, CA	Hospital	DHW, boiler makeup water	$97,000
U.S. Military Academy, West Point, NY	Power plant	Boiler makeup water	$30,000
U.S. Naval Academy, MD	Dining hall	DHW	$25,000

Table 2. FY93 DoD fuel cells operational experience.

Site	Acceptance Date	Run Hours	Down Hours	Unadjusted Availability	Water Chemistry Down Hours	Water Chemistry Adjusted Availability
U.S. Army Soldier Systems Command, MA	2/9/95	13,050	2,638	83%	1,800	94%
Naval Education Training Center, Newport, RI	2/10/95	13,855	1,805	88%	0	88%
934th Airlift Wing, MN	2/16/95	11,662	3,877	75%	2,428	89%
MCB Twenty-Nine Palms, CA	6/23/95	7,549	4,847	61%	3,556	85%
Kirtland AFB, NM	9/17/95	5,811	4,594	56%	3,053	79%
Fort Eustis, VA*	9/18/95	5,517	4,852	53%	3,173	77%
Nellis AFB, NV	10/16/95	5,065	4,639	52%	3,509	82%
Picatinny Arsenal, NJ	10/26/95	7,297	2,171	77%	1,906	96%
MCB Camp Pendleton, CA	10/29/95	5,919	3,472	63%	2,635	88%
U.S. Military Academy, West Point, NY	12/13/95	7,700	612	93%	0	93%
Fleet Total		83,425	33,506	71%	22,059	88%

*Water Chemistry Down Hours include hours during the Winter of 1995 that Fort Eustis chose to shut down the fuel cell due to high gas prices.

Water Chemistry Problems

In January 1996 (approximately 7 months after the initial startup), the ONSI PC25B™ power plant at MCB Twenty-Nine Palms, CA was shut down when overheating and low voltages were detected in the cell stack. In the months before the shutdown, the unit had also experienced a decrease in water treatment resin life. Similar symptoms were detected in three other DoD power plants, all located in the southwestern United States. These plants were temporarily shut down while the cause of the problem was investigated. The cell stack from the Twenty-Nine Palms unit was returned to the ONSI factory for examination (and later replaced with a new stack).

The problem was identified. The stack cooling loop (including the cell stack coolers) had become restricted or plugged with corrosion products. Also, as noted above, reduced resin life was a maintenance problem (although less catastrophic than the cooling loop restrictions). The causes for the cooling loop restrictions and the reduced resin life were determined to be:

- use of site makeup water, which alters water chemistry
- increased corrosion resistance of the PC25B™ condenser (as compared to the PC25A™).

Use of site makeup water alters water chemistry by introducing additional silica in the system and by drastically changing water conductivity (ionic load) in the system. Water in the southwest has the highest silica levels in the United States. The PC25B™ tends to use more site makeup water than the PC25A™, due to the smaller condenser, which reduces the internal water recovery, and also due to a control logic, which enhances heat recovery, but is less favorable to water collection/storage. The capability of the power plant to internally recover water (instead of using site water) is reduced by high ambient temperatures such as found in the Southwestern United States. The PC25™ B has a smaller water tank and working inventory (66 gal compared to 97 gal on the PC25A™).

Increased corrosion resistance of the PC25B™ condenser reduces the ability to tie up silica at locations within the system where it is less harmful; increasing silica at places where plugging can occur. Similarly, the increased corrosion resistance contributes to less phosphoric acid being consumed within the system, causing it to enter the water tank where it contributes to reduced life of the resin. Countermeasures taken were to:

- add steel sheets in condenser as sacrificial material for water chemistry
- add 1 micron filter after last resin bottle to remove silica

- avoid adding untreated water to loop during routine changes of demineralizer bottles
- increase water tank size
- reset controls for maximum water recovery
- add water treatment to site makeup water line.

The 10 DoD PC25B™ power plants located throughout the United States were examined for water chemistry problems. Where there was plugging of the cooling systems, the plant cooling manifold underwent an intricate cleaning procedure. As of August 1996, all 10 plants were operational. Monitoring continues.

As of December 1996, the 10 DoD PC25B™ power plants have responded very positively to the countermeasures taken. For example, at the PC25B™ power plant installed at MCB Twenty-Nine Palms, CA, the water treatment system resin life has increased by a factor of five and the turbidity (indication of proper water chemistry) has been reduced by a factor of 10. Similar improvements are being noted at all sites in the southwestern United States.

Electrical/Thermal Output and Environmental Impact

As stated earlier, fuel cells are electrochemical power generators that can attain very high electrical energy conversion efficiencies while operating quietly with minimal polluting emissions. In addition, by-product thermal energy generated in the fuel cell is available for cogeneration of hot water or steam.

Table 3 summarizes the monitoring results of the installed fuel cells in terms of cumulative electrical output (megawatt-hours (MWh), cumulative thermal output (MBtus), and estimated amounts of pollution abated (tons* of S0x, N0x, and $C0_2$).

FY94 DoD Fuel Cell Demonstration Program

The FY94 Defense Appropriations Act provided $6.25M worth of equipment procurement funds per Service "to continue procurement of non-developmental item (NDI) 200 kW phosphoric acid natural gas fuel cells currently in production in the United States." USACERL was again requested to manage this demonstration program for all three Services. Negotiations were conducted with ONSI Corporation

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* 1 ton = 0.907 metric ton.

leading to a contract for the purchase of 18 additional turnkey PAFC Power Plant packages similar to those purchased with the FY93 Appropriation. Installation of these PAFCs is expected to be completed by the end of FY97. Table 4 summarizes the selected sites, building applications, thermal applications, and estimated annual savings, by Service. Note that USACERL will continue to monitor these sites after installation. This accumulation of data will greatly enhance the evaluation of the potential for use of fuel cells within the DoD.

Table 3. FY93 DoD fuel cells electrical/thermal output and environmental impact.

Site	Acceptance Date	Cum. Electrical Output (MWh)	Cum. Thermal Output (MBtus)	SOx Tons Abated	NOx Tons Abated	CO_2 Tons Abated
U.S. Army Soldier Systems Command, MA	2/9/95	2,268	1,373	11.5	5.1	1,698
Naval Education Training Center, Newport, RI	2/10/95	2,419	3,390	12.2	3.7	1,870
934th Airlift Wing, MN	2/16/95	2,084	0	8.5	8.5	2,079
MCB Twenty-Nine Palms, CA	6/23/95	1,280	442	1.8	0.4	135
Kirtland AFB, NM	9/17/95	883	1,420	2.8	4.2	1,074
Fort Eustis, VA	9/18/95	1,011	335	10.0	1.9	398
Nellis AFB, NV	10/16/95	821	1,274	1.2	3.2	803
Picatinny Arsenal, NJ	10/26/95	1,414	6,355	5.5	0.9	110
MCB Camp Pendleton, CA	10/29/95	1,014	1,858	1.4	0.3	106
U.S. Military Academy, West Point, NY	12/13/95	1,413	6,807	5.8	1.8	487
Fleet Total		**14,607**	**23,255**	**60.7**	**30.1**	**8,760**

Table 4. PAFC sites, building and thermal applications, and estimated annual savings by Service.

Site	Building Application	Thermal Application	Est. Savings
Air Force			
911th Airlift Wing, PA	Central Heat Plant	Space Heat	$60,150*
Laughlin AFB, TX	Hospital	Space Heat/Reheat/DHW	$41,775
Westover ARB, MA	Central Boiler Plant	Boiler Make up/Condensate	$53,000
Little Rock AFB, AR	Hospital	Space Heat/Reheat	$90,000
Davis Monthan AFB, AZ	Gymnasium	DHW/Absorption Chiller	$61,396
Edwards AFB, CA	Hospital	DHW/Space Heat	$93,000
Barksdale AFB, LA	Hospital	Space Heat/Reheat	$40,000
Army			
Watervliet Arsenal, NY	Central Boiler Plant	Boiler Make up Water	$76,000
Fort Huachuca, AZ	Barracks	Space Heat/DHW	$66,816
Fort Richardson, AK	Armory Building	Space Heat/DHW	$67,273
Fort Bliss, TX	Laundry	Process Hot Water	$56,000
Pine Bluff, AR	Boiler Plant	Boiler Feed Water	$61,000
Navy			
NAS Jacksonville, FL	Hospital	Space Heat/Reheat/DHW	$90,000
NAS Fallon, NV	Galley	DHW	$58,438
Stennis Space Center, MS	Office Building	Space Heat/Reheat	$38,969
Navy Subase-Groton, CT	Boiler Plant	Boiler Feed Water	$98,394
CBC, Port Hueneme, CA	Swimming Pool	Pool	$66,000
DoD			

* Contingent upon gas rate negotiation.

3 FY93 Program Site Descriptions

Natick Soldier Systems Command, MA

Natick Soldier Systems Command is located approximately 25 miles west of Boston, MA (1 mi = 1.6 km). The climate is typical of the northeast portion of the United States with temperatures in the teens in the winter and the 80s and 90s (°F; where °F = [°C x 1.8] + 32) in the summer. The site consists primarily of research facility buildings.

Naval Education Training Center, Newport, RI

NETC is located in Newport, RI, approximately 30 miles south of the city of Providence. NETC consists of a wide range of buildings including office buildings, central plants, docking facilities, etc. Temperatures range from the teens in the winter to the mid 90s (°F) in the summer.

934th Airlift Wing, MN

The 934th Airlift Wing is located in Minneapolis, MN at the Minneapolis-St. Paul International Airport. This facility serves as a reserve base for the Air Force and the Navy. The site consists of approximately 40 buildings, including housing, administrative, cafeteria, central energy plant, and other support use buildings. Temperatures for this area range from a design temperature of -16 °F in the winter to a design temperature of 89 °F in the summer. These temperatures do not reflect a correction for wind or humidity. Historical weather data for the airport also shows 6728 heating degree days per year and 662 cooling degree days per year.

MCB Twenty-Nine Palms, CA

Twenty-Nine Palms is located approximately 150 miles east of Los Angeles, CA and is approximately 50 miles northeast of Palm Springs. The location is in a high desert environment where temperatures are usually over 100 °F during the summer months. Winter temperatures can go as low as the 20s or 10s (°F) at night.

Kirtland AFB, NM

Kirtland AFB is located in Albuquerque, NM, directly adjacent to the commercial airport. Sandia National Labs is located on the base. The site consists of a wide range of buildings including office buildings, central plants, airplane hangers, etc. Temperatures range from the teens in the winter to over 100 °F in the summer.

Fort Eustis, VA

Fort Eustis is located in Newport News, VA. The site supports various transportation training functions and contains the Military Transportation Museum. Temperatures at the site range from the 20s to over 90 °F. Historical weather data shows an average of 3,495 heating degree days and 1,422 cooling degree days per year.

Nellis AFB, NV

Nellis AFB is located in Las Vegas, NV. The site is an air training facility and is also home to the Air Force Thunderbirds. Temperatures range from the teens to over 100 °F.

Picatinny Arsenal, NJ

Picatinny Arsenal is located in Dover, NJ, approximately 30 miles west of Newark. The site is a research, development, and test site for advanced weapon systems. Temperatures range from 6 °F to over 90 °F throughout the year.

MCB Camp Pendleton, CA

Camp Pendleton Marine Corps. Base in Oceanside, CA is located approximately 25 miles north of San Diego. Camp Pendleton is home to more than 35,000 marines where they are trained in a broad range of mission-related skills. Temperatures range from the 40s in the winter to over 100 °F in the summer.

U.S. Military Academy, West Point, NY

The U.S. Military Academy in West Point, NY is located approximately 60 miles north of New York City. The Academy has more than 4,000 students enrolled. Temperatures at the site range from the zero to over 90 °F throughout the year.

U.S. Naval Academy, MD

The U.S. Naval Academy was established in 1845 at an obsolete Army post at Fort Severn, Annapolis, MD. The Naval Academy borders the city of Annapolis, the Severn River, and the Chesapeake Bay, and is home to over 4,000 students. Temperatures range from the teens in winter, to over 100 °F in the summer.

4 Conclusions

The 200 kW PAFC power plants installed in this demonstration to date have displaced close to 15,000 megawatt-hours of purchased electricity. Use of the thermal energy by-product (over 23,000 MBtus) of the fuel cells has been used to displace combustion-based, less environmentally friendly production of thermal energy. Estimated net energy savings for each of the 10 installed demonstration sites have varied from $17,000 to $103,000 per year. These are energy savings and do not include environmental cost benefits of using a nonpolluting energy source. The amount of pollutants abated to date include approximately 61 tons of S0x, 30 tons of N0x, and 8,800 tons of $C0_2$.

The 10 installed fuel cells in the DoD fleet are all currently operational and have a combined, nonadjusted availability of 71 percent as of December 1996. The combined adjusted availability, taking into account the down hours due to the water chemistry problems, is equal to 88 percent. Other than the maintenance issues and down times associated with the water chemistry problems, the installed DoD fuel cells have operated without incident, logging over 83,000 hours of run time. Corrective measures implemented to address the water chemistry problems have proven successful thus far.

Fuel cells offer a cleaner and more efficient power source than conventional fossil fuel based technologies and should be utilized as resources permit. However, even with the substantial energy savings, fuel cells are not yet economically competitive with other, more conventional energy production technologies, due to high production and installation costs. However, as production costs decrease, fuel cell technology should prove to be cost-effective. Current industry projections predict mature market installed costs for PAFCs to be less than $2000 per kilowatt (kW). A decrease of approximately 40 percent in PAFC installed costs from the FY93 to the FY94 programs lends credence to these projections. At that time, fuel cell technology should prove to be a viable energy supply alternative for DoD installations with large gas-to-electric cost differentials, especially those installations in need of enhanced air quality.

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